MISSOURI DEPARTMENT OF NATURAL RESOURCES

Schematic Design Daylighting Review
June 15, 2001

The current scheme being developed for the Missouri Department of Natural Resources building has fabulous opportunities for daylighting. In particular we love the way in which you have been able to maximize south and north glazing opportunities, minimize the east and west exposures, and provide a relatively narrow floor plate.

Approaches to daylighting for this building should be a balance between daylight penetration for optimal ambient lighting, and shading to prevent glare and accompanying radiant heat gain. This balance becomes tighter when considering the climate of Missouri, where full shading is desirable during late spring through early fall and some penetration is typically beneficial from late fall to early spring. Quickly the approach to daylighting becomes a formgiver for the building.

Daylighting

Upon review of the schematic design Scheme A (dated 4-24-01), it appears that attention towards optimizing the opportunities for daylighting have been given in the orientation, form, and aesthetic of the design. While the plan is split into two wings, slightly skewed from a true southern orientation (10^0 east of south & 10^0 west of south), the orientation is primarily east/west elongated, which is best for shading control and daylighting potential. Elevations oriented east or west have been minimized, which will benefit unnecessary radiant heat gain from low solar angles. The depth of each wing is appropriate for good daylight penetration, ranging from 60' to 80' at its maximum with equally spaced light wells positioned roughly 30' from the southern elevation. These dimensions should remain within these maximums with some recommendations for consideration on the southern elevations to optimize daylighting potential. These recommendations will be further outlined under specific topic areas within this review.

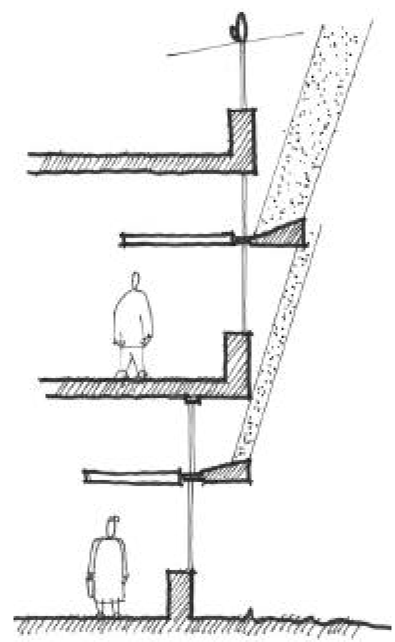


Fig. 1. Quantity of light received by Scheme A light shelves.

Pre-Cast Modular Panel System

The pre-cast modular panel system developed for the south façade(s) begins to communicate a proper approach towards daylighting and shading. This panel system also adequately integrates these strategies into the structural system, thereby limiting the impact of potential future "value engineering" exercises. The panel system provides moderate levels of shading, both horizontally as well as vertically on the 2nd and 3rd floors. However, the 3rd and 1st floors are a bit over-shaded due to the 2'6" and 3'0" outward floor plate overhangs. This limits the quantity of light received by the light shelves directly from the sky, which will impact the depth of daylight penetration (Fig. 1). Additionally, the 4th floor's light shelf is completely cut off from moderate to high solar angles, thereby having a direct impact on effective daylighting of the 4th floor.

Opportunities exist for modifying this scheme to optimize the daylighting potential. The following bullet points quickly outline recommended approaches.

- Increasing the exposure of the light shelves to receive more light directly from the sky, especially during the summer, by limiting or eliminating self-shading (e.g. straightening the building vertically).
- Adding an interior light shelf to the upper and lower levels.
  - Design depth of interior light shelf as a function of low winter sun angles (profile angle).
- Greater depth of interior light shelves to maximize the effect of light penetration by brightening ceiling surfaces deeper into the interior.
  - Design depth of interior light shelf as a function of low winter sun angles (profile angle).

- Opening the southern façade more towards the equinox sun angles (e.g. stepping the building to the north) to even daylight levels year around.

Light Wells

The light wells are good strategies for providing daylight into interior spaces where the depth of the building begins to become too deep. The roof overhang over the light wells will limit the ability to harvest direct and/or reflected high solar angle light into the light well, which will further favor greater quantities of daylight in the winter than in the summer. Ideally, such a strategy would optimize daylighting all year. Recommendations include:

- Incorporation of a light reflector a the light wells to reflect and diffuse low, as well as high, sun angles towards the fabric diffuser.
  - Roof overhang could be pulled back to allow exposure to high sun angles.
  - Light reflector could be specularly selective.
- Direct low winter sun angles towards surfaces to decrease opportunities for direct beam glare at 4th floor

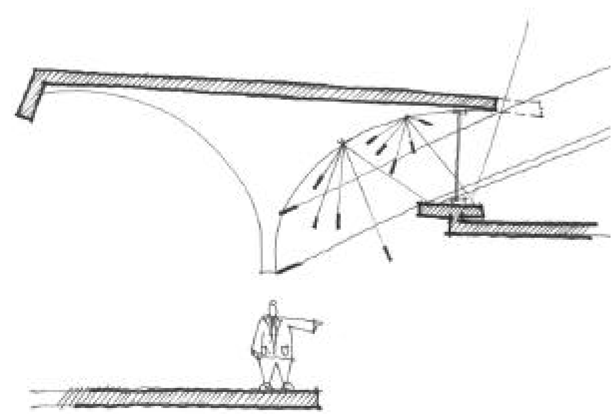


Fig. 2. Light well design strategy.

Design Opportunities

The following graphics represent opportunities for enhancing the daylighting potential with this building. These design strategies are intended to present relative levels of enhancement, where the fundamental principles could be redeveloped into a different aesthetic.

Option 1:

This option largely maintains the original design, with modifications to the 4th floor to increase daylighting effectiveness. Light shelves have been sized in conjunction with sun angles to decrease, or eliminate, glare potential and increase shading on fenestrations below the light shelves. The exterior light shelves on the 1st and 3rd floors are still largely cut off from maximum exposure to the sky.

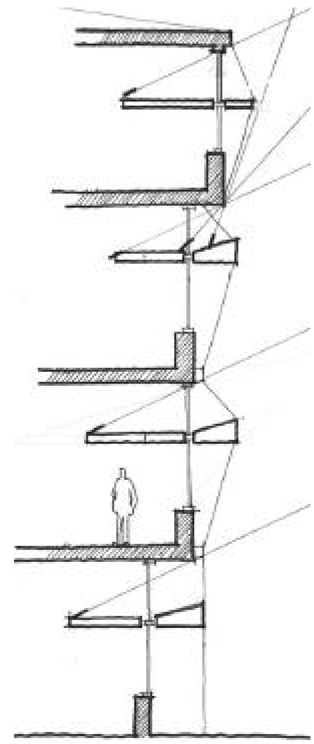


Fig. 3. Option 1 Daylighting design strategy.

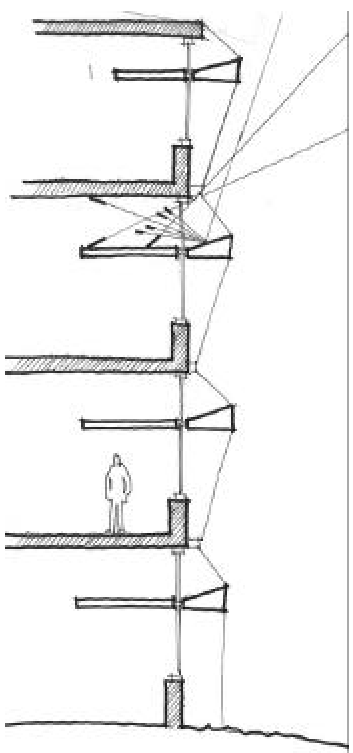


Fig. 4. Option 2 Daylighting design strategy.

Option 2:

This option again largely maintains the aesthetic character of the original design, with attention to the 1st and 3rd floor's exterior light shelves. Straightening the south façade "opens" this elevation to increase daylight harvesting potential. With this option, the daylighting levels are evened out on all floors. As with option 1, the depth of the light shelves have been increased to provide adequate shading and glare control.

Option 3:

Option 3 begins to provide some opportunities for evening the daylight levels all year around, specifically more in the summer. By stepping the building back to the north, the south façade is "opened" up further to receive high summer sun angles. Appropriate levels of shading are maintained.

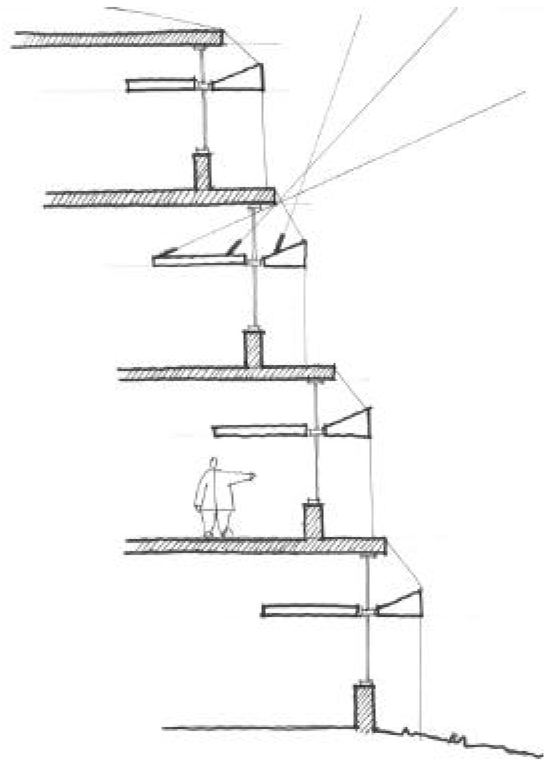


Fig. 5. Option 3 Daylighting design strategy.

Light Pipes:

The following design strategy is presented as a method for enhancing the daylight potential to deeper sections of the building. This concept is in a sense a horizontal light pipe. Initial studies of such a design strategy were developed by the Lawrence Berkeley National Laboratory in California (see Fig 10). We feel modifications of this design should be refined to be more applicable to this project.

The idea behind the horizontal light pipe is to supplement perimeter daylight, in most conditions adequately supplying light up to 15'0"into the building, over a larger floor area (e.g. beyond 15'0" perimeter). The light pipe appears, in section, very similar to that of a light shelf. In actuality, it can be much more integrated into the ceiling plane, potentially creating less disruption to the exterior aesthetic and/or interior. A couple of options for the light pipe's integration into this project are included below.

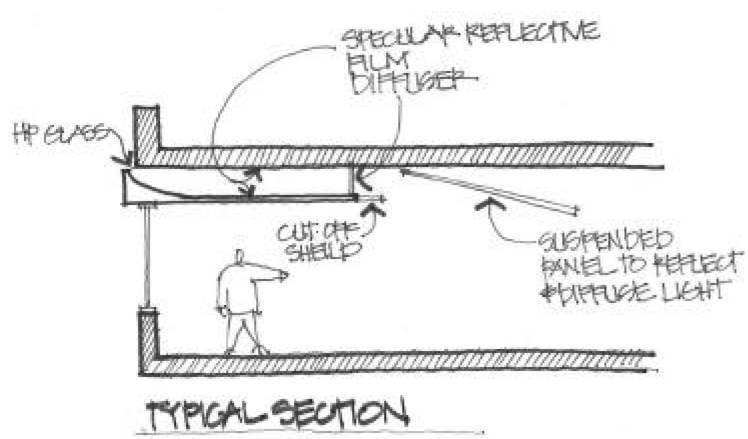
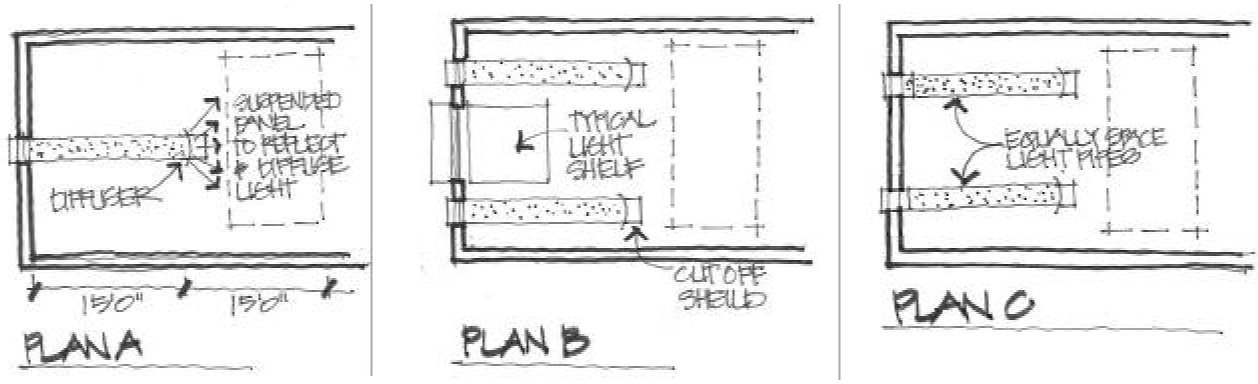


Fig. 6. Light pipe design option per Mo Department of Natural Resources.

LBL studies have indicated that this design strategy "can introduce adequate



Figs. 7-9. Light pipe plan options per Mo Department of Natural Resources.

ambient daylight for office tasks in a 15 to 30 ft zone of deep perimeter space" and presents increased potential energy savings.

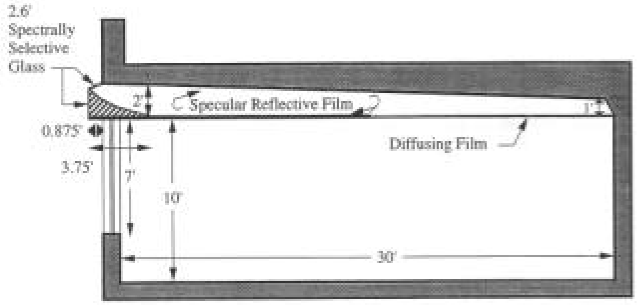
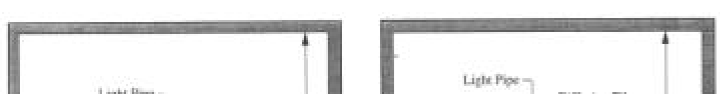


Figure 3. Section of trapezoidal light pipe design (Light Pipe C).



Shading Analysis

Shading masks give an indication of how solar impacts are controlled by the building façade. Shading windows intercepts radiant solar heat gain, and thereby has a large impact on building cooling loads. In addition, shading is important for visual comfort, and helps prevent direct glare from sunlight.

There are several techniques for plotting the sun's path upon a flat projection including orthographic projection, stereographic projection, and equidistant projection; each have their roots in the measurement devices which were used to develop them. Of these, the equidistant projection has become the most widely used method for constructing a sun-path diagram, and shading profile. It is the basis for the widely distributed "Sun Angle Calculator", a circular protractor with inter-changeable plates that have the sun's path already drawn for different latitudes and uses a "true altitude" cursor to calculate the angle of the shading device. The well-photocopied versions of sun-path diagrams and shading mask protractors that appear in the AIA's Architectural Graphic Standards are based on the equidistant projections and the shading mask protractor. This equidistant projection is also the method used in the Solrpath program for shading analysis.

These round “shading masks” describe the control of impacts at the facade. The horizon is the outermost circle, and the center of the mask is directly overhead. Radial lines indicate azimuth, or location in plan (north, east, etc), and the concentric circles indicate altitude in increments of 10 degrees, with 90 degrees indicated directly overhead. The red lines indicate the suns’ path, rising in the east, setting in the west and higher in the summer than in the winter. Lines indicating the hours of the day vertically intersect these seasonal lines completing the description of the suns path over a year.

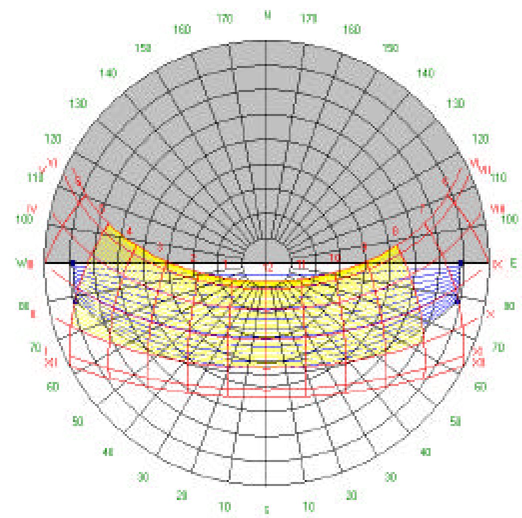


Fig. 11. Typical shading mask for a south façade window.

On top of the sun’s path, many things can be plotted, most usefully we can plot the times that shade is desired, and the geometry of a given window to show the times it will shade. The times when shading is desired for heat gain and glare control is shown in yellow, and the blue areas indicate the window shading. In general horizontal shading devices like overhangs create segmental curves, and vertical devices like fins create masks with radial patterns.

The following shading masks (Figs. 12-15) pertain to the Missouri Department of Natural Resources, and begin to illustrate this balance between fully shading and allowing some solar penetration for particular times of day during particular seasons (designated by the yellow highlighted areas). One should note that allowing direct gain, which may offer some benefit during the winter, would need particular attention not to create excessive glare conditions.

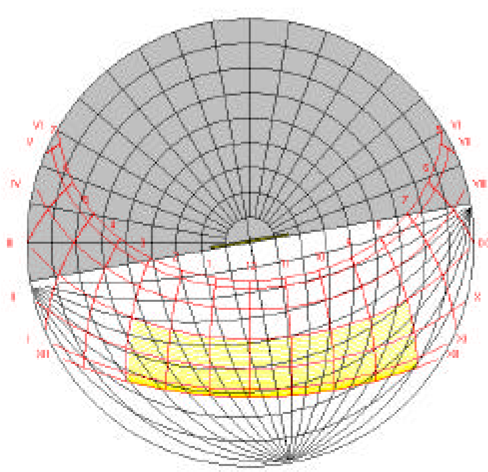


Fig. 12. Optimal penetration for west wing oriented 10^0 east of south.

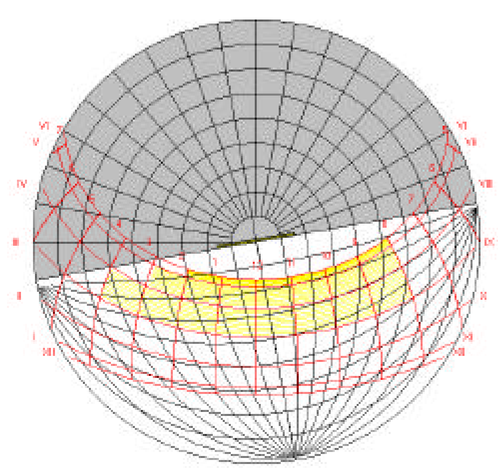


Fig.13. Optimal shading for west wing oriented 10^0 east of south.

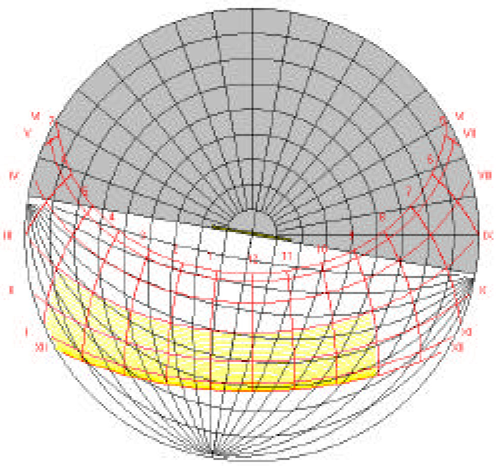


Fig. 14. Optimal penetration for east wing oriented 10^0 west of south.

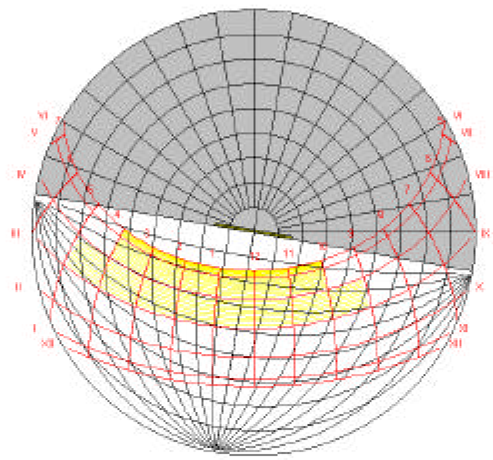


Fig. 15. Optimal shading for east wing oriented 10^0 west of south.

With this given criteria, horizontal and vertical shading elements can be overlaid and dimensionally defined. The original design, Scheme A, has incorporated both horizontal and vertical elements in an attempt to provide shading along with daylight diffusion. The following shading masks represent the east and west wings and amount of horizontal and vertical shading necessary to provide full shade consistent with figures 13 and 15 and/or allow some penetration consistent with figures 12 and 14. For both wings these dimensions are consistent. The horizontal overhang approaches 6'6" in depth to provide full shade during the months of April thru September. This depth will also permit adequate opportunities for some penetration during the months of October thru February. A horizontal overhang alone would not be adequate to shade during the early morning or late afternoon times of day. Thus, vertical shading devices, or fins, can be incorporated to supplement this need. These vertical fins are sized approximately 1'0" less than that of the horizontal overhang. Again, this combination provides adequate shading along with some penetration.

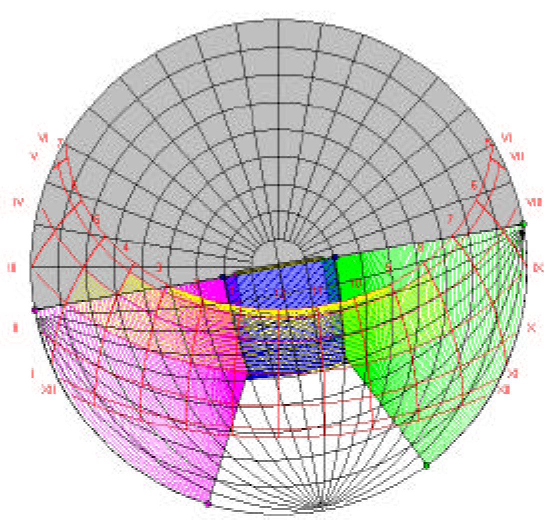


Fig. 16. SSE Fully shaded.

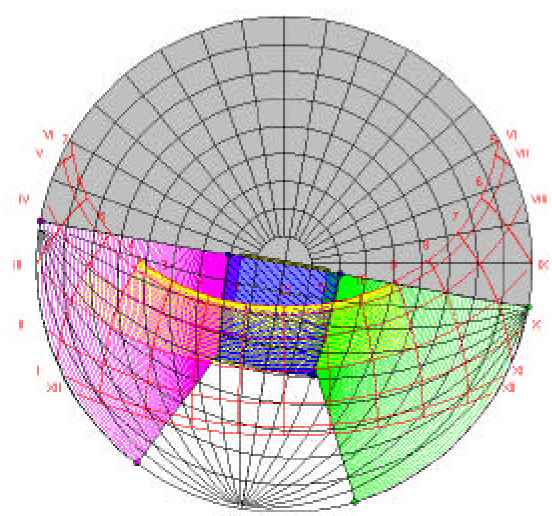


Fig. 17. SSW Fully shaded.

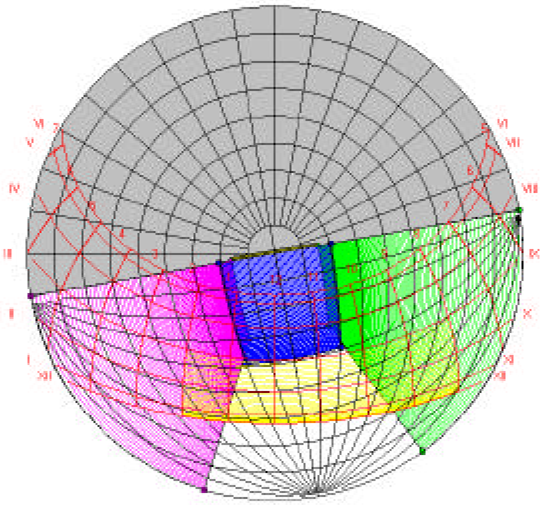


Fig. 18. SSE Allowed penetration.

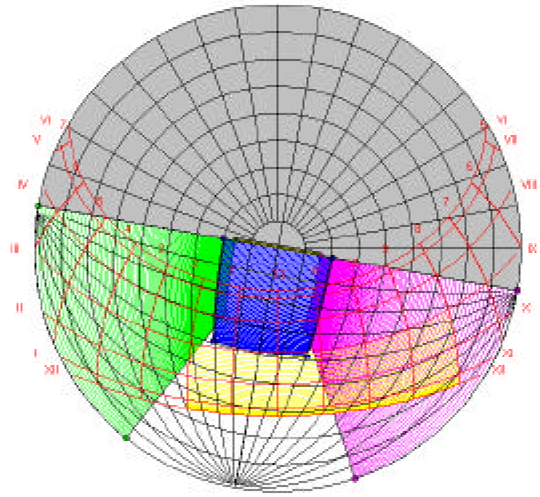


Fig. 19. SSW Allowed penetration.

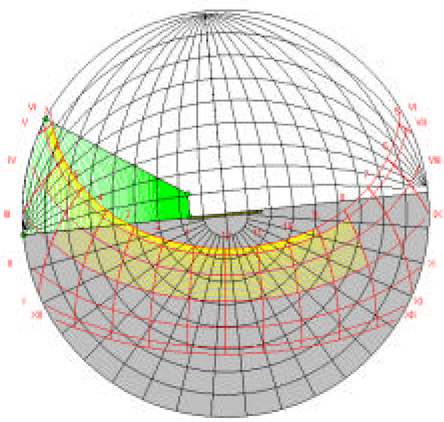


Fig. 20. NNW shading strategy.

Figure 20 is a shading mask for the north façade of the west wing. Late summer afternoon/evening sun angles could present potential glare issues for occupants. The critical times are 4pm and beyond, which may pose little concern, as the building would typically be vacant. However, Scheme A integrates a vertical fin as apart of the structure, which sized appropriately could be beneficial for providing shade and glare control. The dimension of this element, approximately 2'0", is not as extreme as that on the south façade.

Updated Shading Analysis

The following analysis further defines an optimized approach towards daylighting control strategies for the Missouri Department of Natural Resources. This is in conjunction with the latest design refinements to Scheme A (dated 5-23-01), and provide an added layer of detail for the development of the design.

Vertical Sun Control Devices

The adjacent shading diagrams (enlarged for better clarity) give further understanding of the effect of the vertical structural fins on sun control. These elements are useful in controlling glare from low sun angles (e.g. early morning and late evening). The vertical fins should not be considered as light redirecting devices. Unlike a horizontal light shelf, a specular vertical surface will reflect light downward, towards occupants' eyelevel, creating glare. Matte surfaces are best for avoiding glare and diffusing daylight.

As a typical office building, the hours of occupation assumed is between 8am and 5pm. Providing shading/sun control during these hours is optimal. Two window sizes have been studied, 12'6" and 8'4" based on information provided. Figures 21 & 22 show a

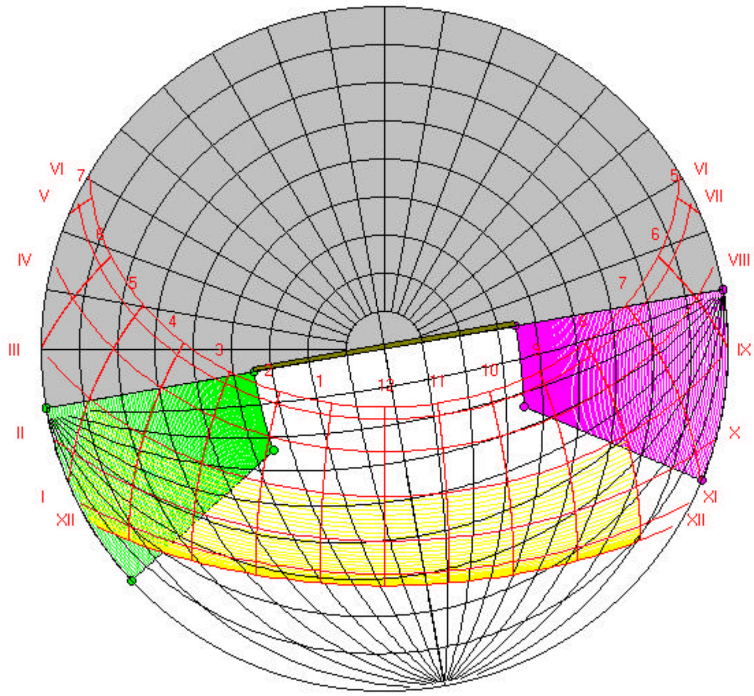


Fig. 21. 12'6" window & 4'0" vertical fin (winter).

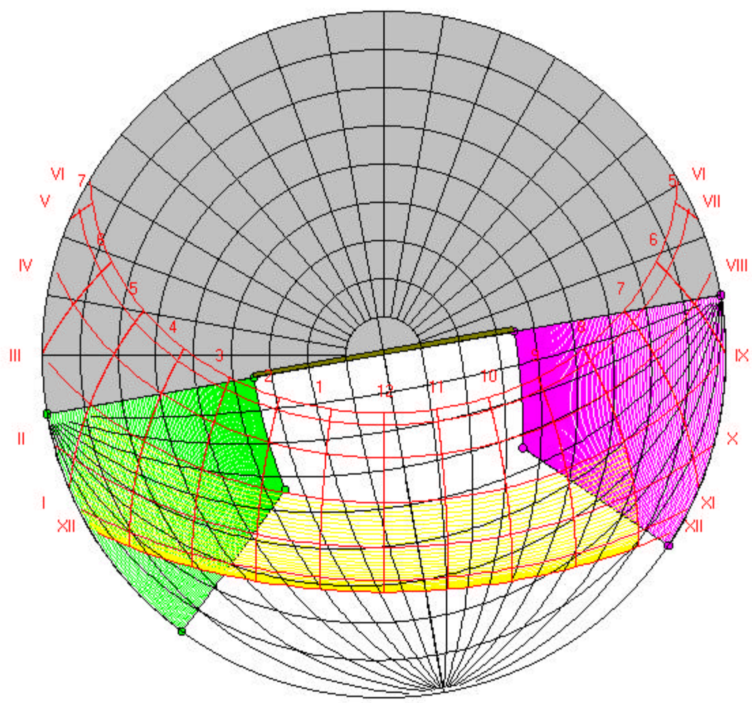


Fig. 22. 12'6" window & 6'0" vertical fin (winter).

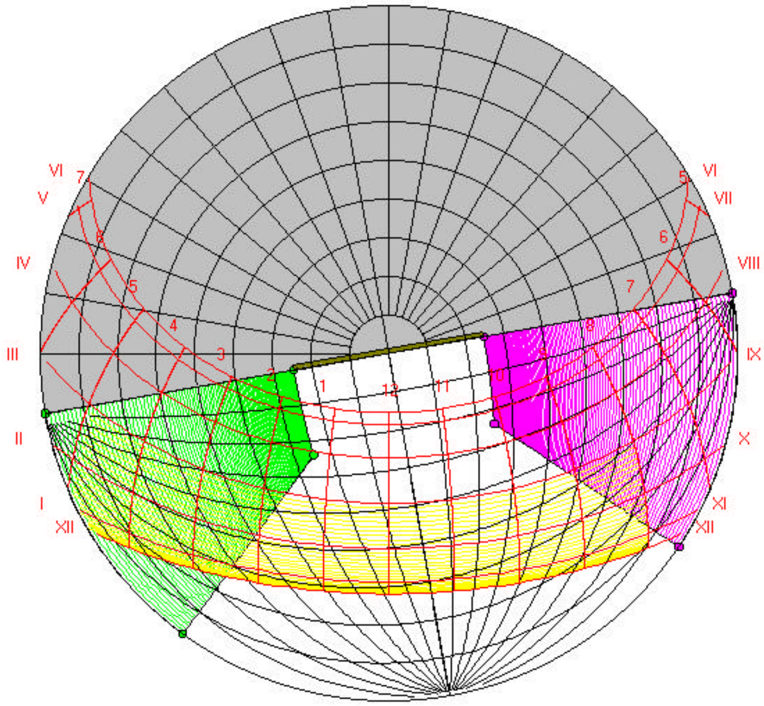


Fig. 23. 8’4” window & 4’0” vertical fin (winter).

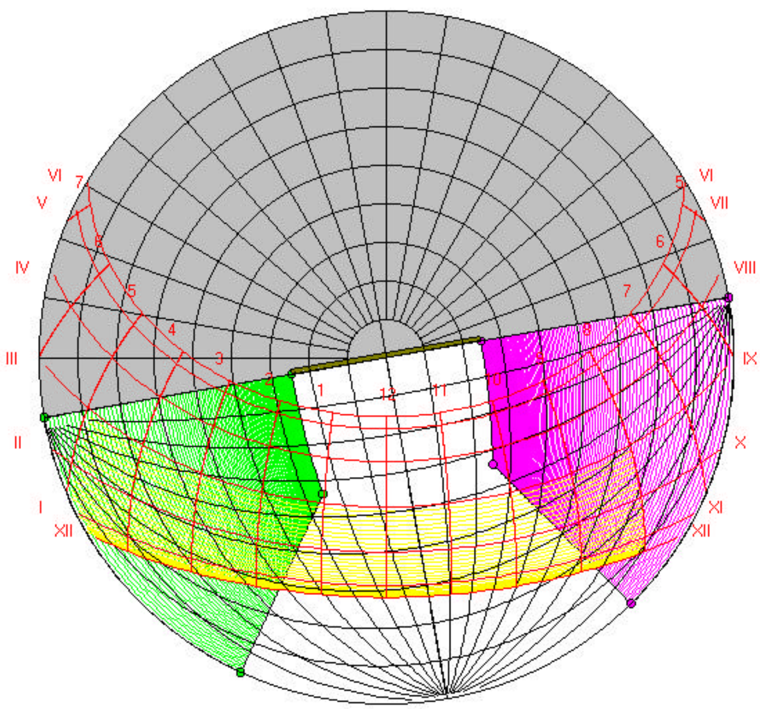


Fig. 24. 8’4” window & 6’0” vertical fin (winter).

12’6” wide window and indicate the effectiveness of a 4’0” deep and 6’0” deep vertical fin respectively.

Figures 23 & 24 show an 8’4” wide window and indicate the effectiveness of a 4’0” deep and 6’0” deep vertical fin respectively.

As can be seen, vertical fins will provide good sun control in late afternoon periods (@2-5pm from Oct.-Feb.) for both window widths. However, a narrower window will allow more sun control in early morning periods. The depth of the vertical fin needs to be a balance with the desired views to be maintained. Views become sacrificed as sun control is increased.

As might be expected, vertical fins will provide greater control during the same desired times of day during the summer months. This is due to a more northern orientation of the sun during the mornings and afternoons. In other words, less depth is required for greater control from 8-9am and 2-5pm. Thus, while the winter months are the most critical to design to, without considering the summer months, too much shading can be created. Again, optimizing the depth of vertical fins is a balance between sun control, views, and aesthetics.

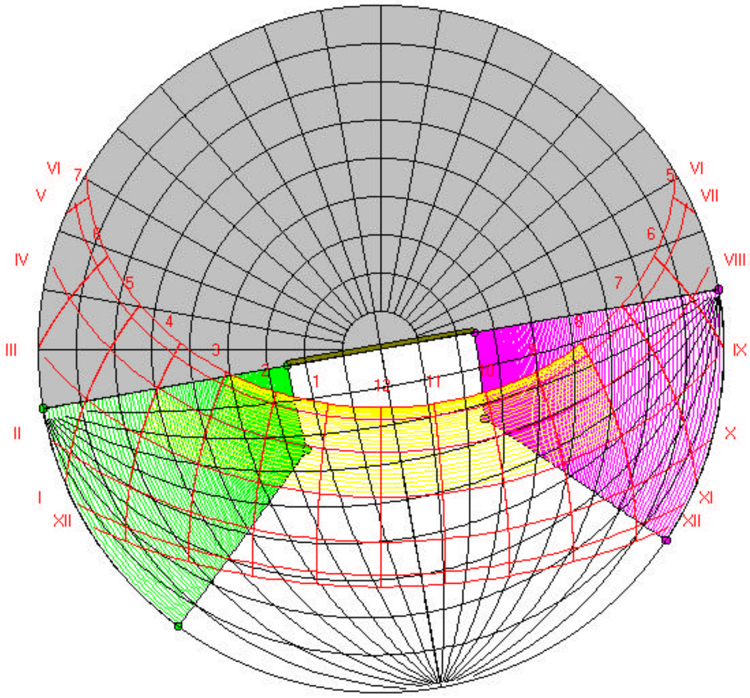


Fig. 25. 8’4” window & 4’0” vertical fin (summer).

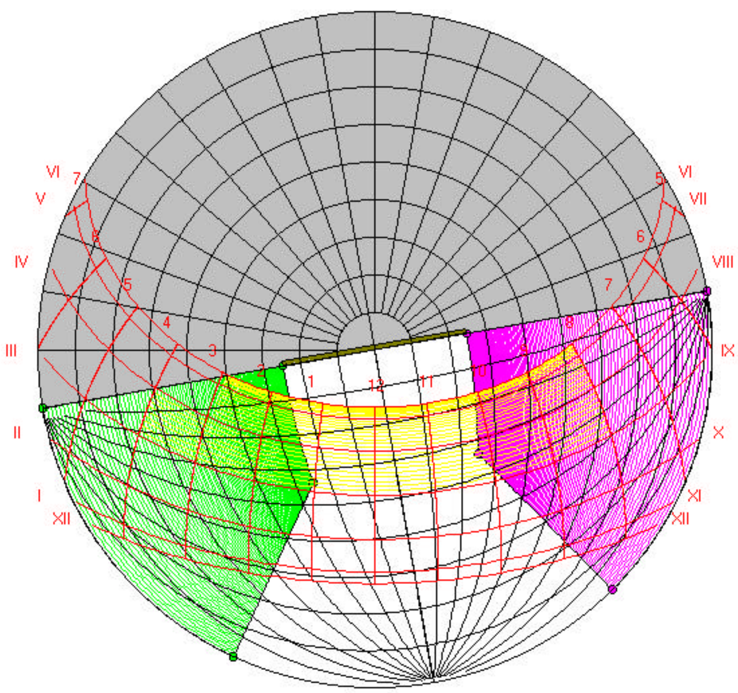


Fig. 26. 8’4” window & 6’0” vertical fin (summer).

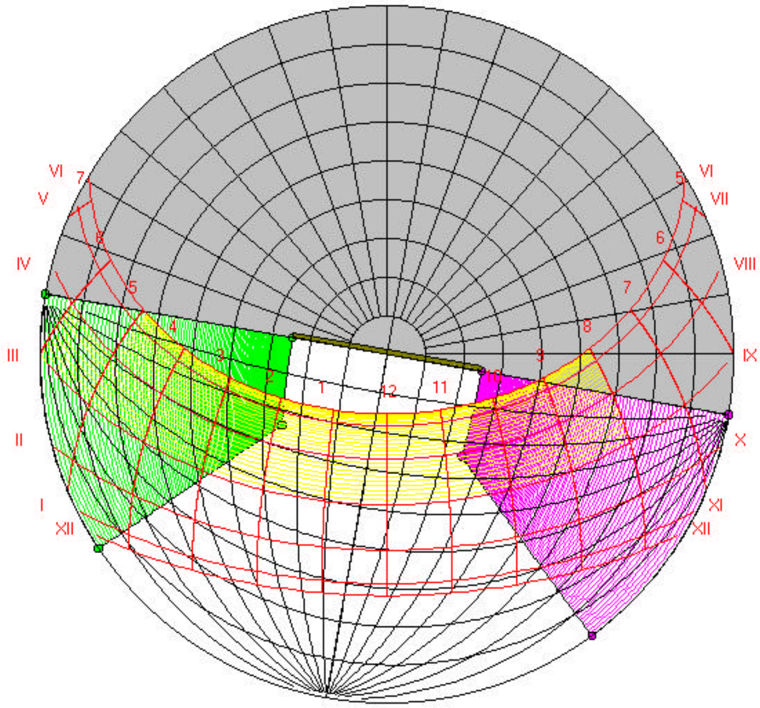


Fig. 27. 8’4” window & 4’0” vertical fin (summer).

The east wing can take advantage of similar criteria as that of the west wing as far as vertical sun control devices is concerned. A 4’0” vertical fin depth will provide adequate control between @2-5pm during the summer months, and the morning is not an issue because of the orientation away from sunrise, even during winter months. However, the afternoon during winter months is compromised at this depth.

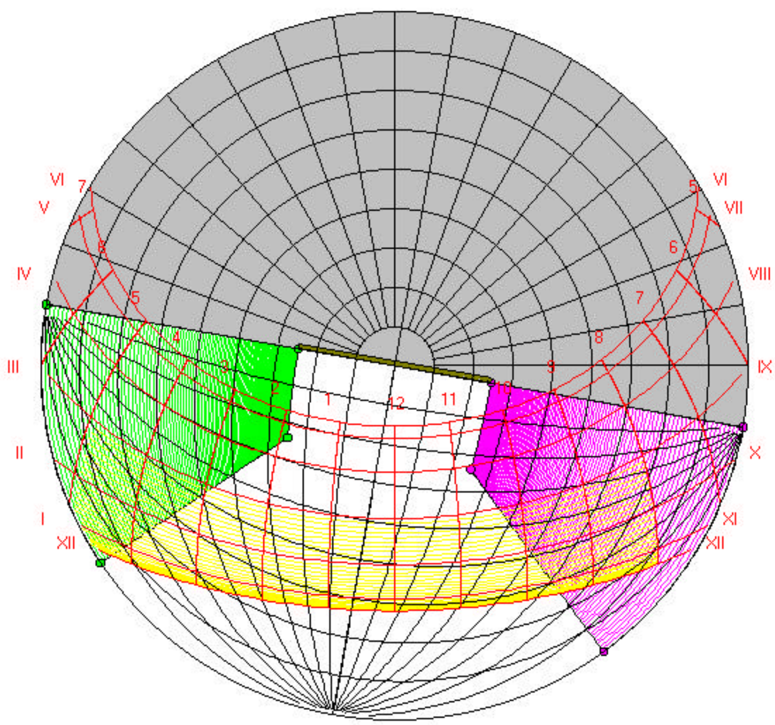


Fig. 28. 8’4” window & 4’0” vertical fin (winter).

Horizontal Sun Control/Light Shelves

Horizontal sun control devices are intended to provide shading as well as redirect daylight. The specifics of the light shelf need to be designed with similar considerations as that of the vertical fin – performance, aesthetics, and views. Shading and redirecting the high solar angles associated with the summer months tends to be the guiding factor where exterior light shelves are concerned (see figures 30 & 31). Adequate shading of low winter solar angels becomes more difficult because the light shelves become much too deep, creating significant aesthetic issues.

The exterior light shelves can be constructed in a number of different ways – concrete, steel, and aluminum. The use of concrete is a concern from the added structural needs, thus a pre-manufactured or custom-made light gauge metal light shelf is seemingly more appropriate.

Winter control will require a balance between vertical fins and an interior light shelf. As has been demonstrated, the vertical fins will provide sun control during the first hour (@8-9am) and for several hours (@2-5pm) during the late afternoons. Control between 9am and 2pm will rely on an interior light shelf or some combination of an interior light shelf and an additional reflector. An interior light shelf could provide complete sun control, but would require an extremely deep shelf, up to 30-40 ft in some instances. These deep penetrations are a concern for occupants that are closer to the building core and the associated glare potential. This condition could be controlled with horizontal blinds. This solution would benefit by having two sets of blinds, one for the lower window and one for the upper clerestory window, so that separate controls are available.

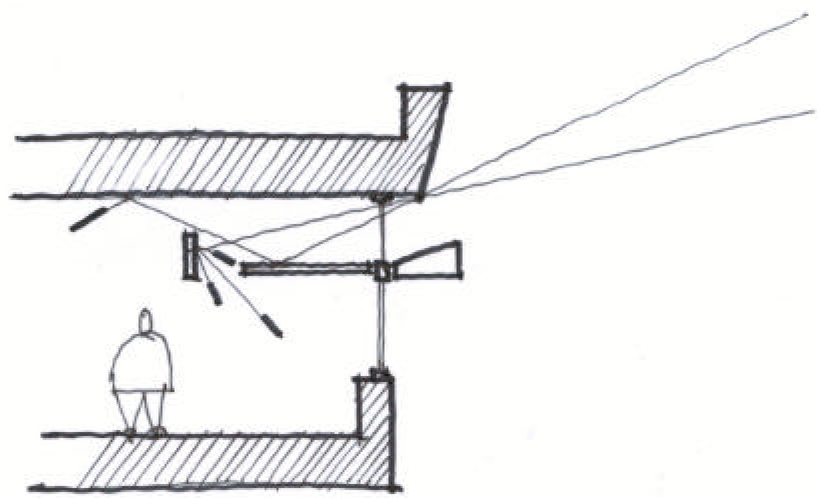


Fig. 29. Interior light reflector.

Another solution to this issue would be to combine a baffle beyond the 5’0” light shelf that is currently being considered (see Figure 29). This baffle could be a series of smaller baffles to keep vertical heights of these elements to a minimum. This baffle can be made of off-the-shelf materials (e.g. metal frame and gyp board) and attached to the edge of the interior light shelf or simply be hung from the ceiling.

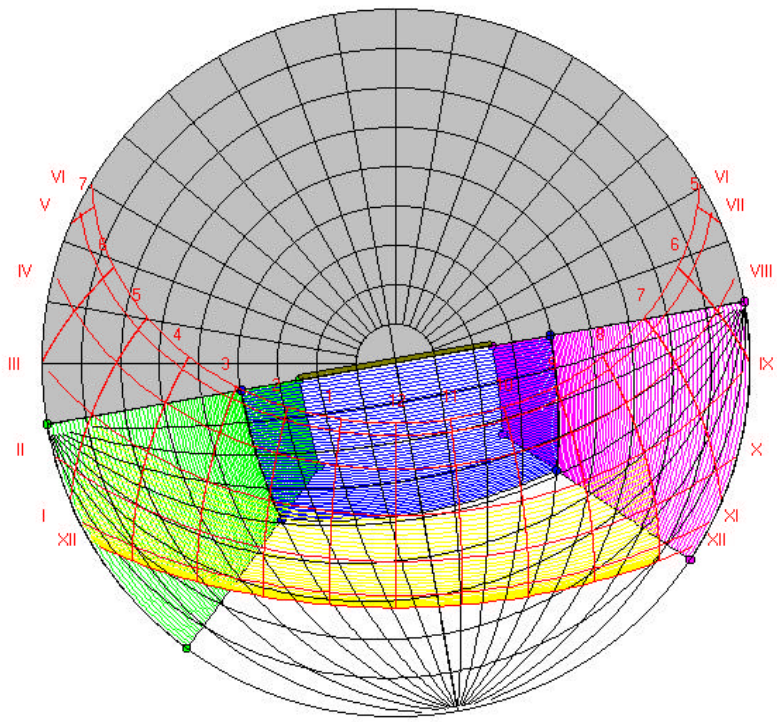
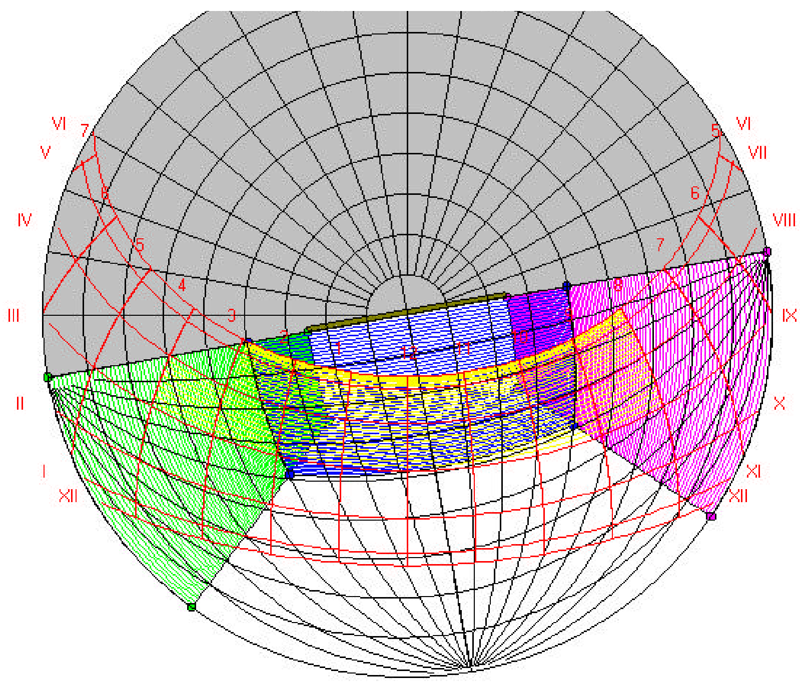


Fig. 30. 8'4" window & 4'0" light shelf (winter).



;. 31. 8'4" window & 4'0" light shelf (summer).

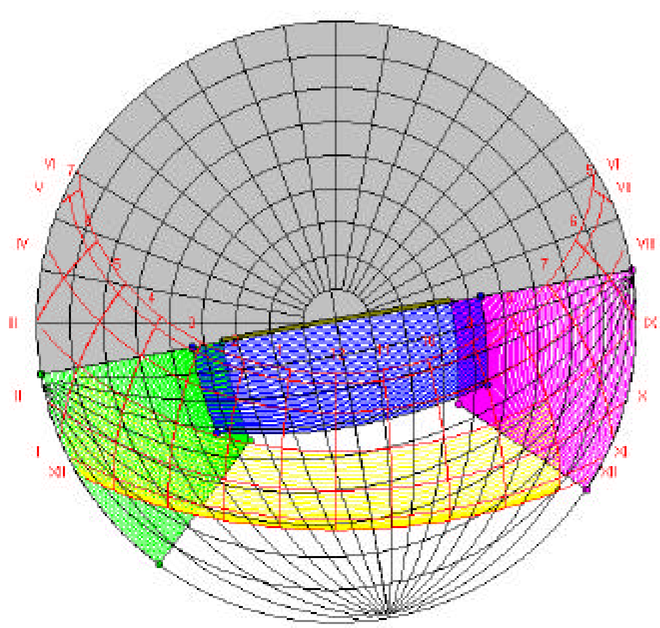


Fig. 32. SSE orientation-12’6” window/4’0” light shelf/6’0” vertical fins (winter).

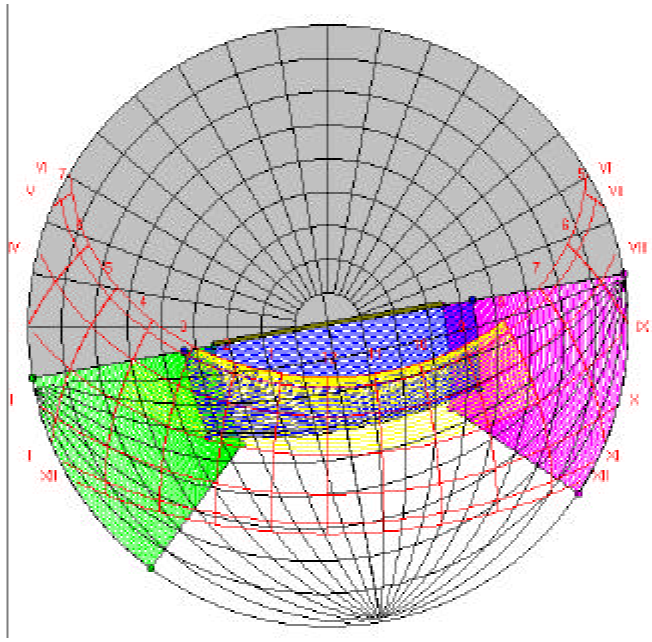


Fig. 33. SSE orientation-12’6” window/4’0” light shelf/6’0” vertical fins (summer).

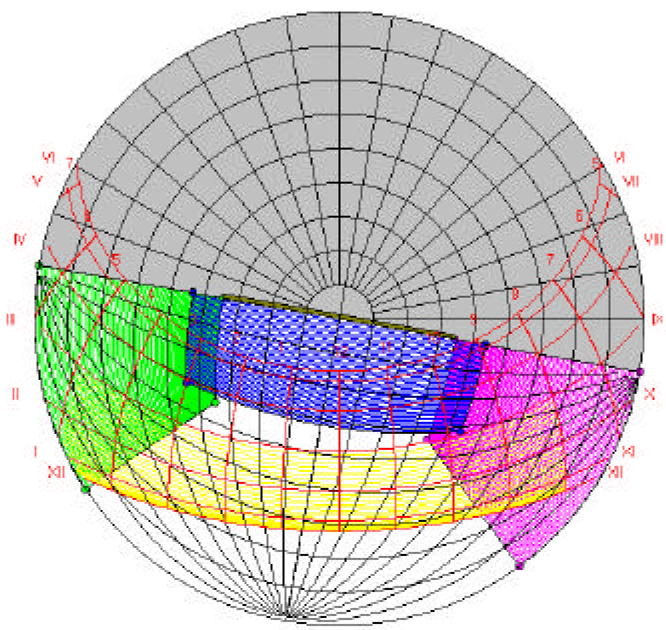


Fig. 34. SSW orientation-12’6” window/4’0” light shelf/6’0” vertical fins (winter).

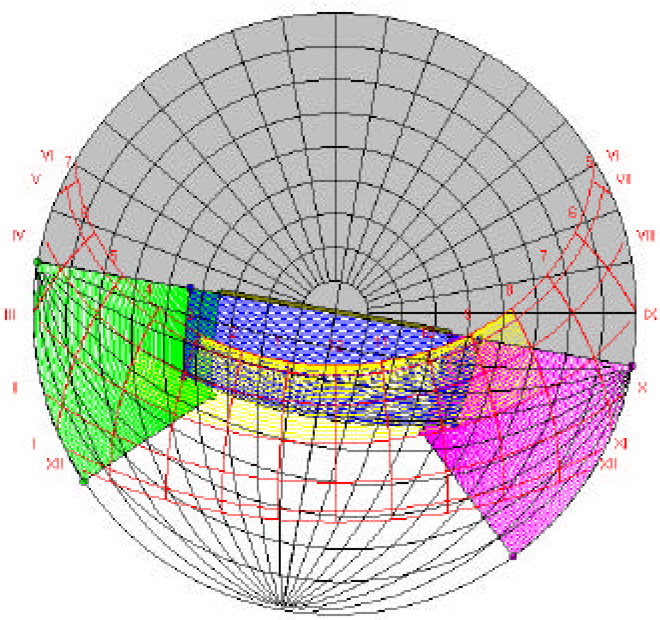


Fig. 35. SSW orientation-12’6” window/4’0” light shelf/6’0” vertical fins (summer).

As can be seen in figures 33 and 35, adequate shading is provided from the 4’0” light shelf and 6’0” vertical fins on the 12’6” window. The depth of the light shelf should be increased about 1’0” more to cover the early afternoon hours (12pm-2:30pm) in the summer. Heat gains during these periods are intense. The light shelf provides no shading during the winter for either wing. Specifying a glazing with a low shading coefficient and lower light transmittance will assist where the light shelf falls short.